Decision-making Methodology & Selection Tools for High-performance Window Systems in U.S. Climates

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ABSTRACT

Selecting a glazing system requires an understanding of a series of variables such as, glazing type, frame type, window area, orientation, shading devices, and the use of daylight. These variables that make up the window system all affect the building's energy performance and the human factor issues relating to the building's occupants. Using simulation and decision-making tools early in the design process help to understand the impacts of these variables and then these variables can be understood and adopted or rejected early in the design process of a high-performance building. The decision-making methodology for high-performance window systems can be climate specific. For example, heat gain through the glazing system should be restricted or controlled in a cooling-dominated climate—which may allow for the downsizing of a building's cooling system. On the contrary, heat gain through the glazing system may be beneficial in a heating-dominated climate—allowing for some passive solar gain. In both these cases, the orientation, glazing type, daylighting (ratio of VT and SHGC), and shading devices are each important but play different roles—all of which impact the design and performance of a building. Fenestration simulation tools, such as RESFEN (residential) and COMFEN (commercial), give the decision-maker(s) early feedback on the impacts of these variables and aid in integrated design decisions. Both of these simulation tools are developed and maintained by the Windows and Daylighting Group at Lawrence Berkeley National Laboratory (LBNL) and are freely available. These simulation tools, along with paper and web-based tools/information developed by a cooperative effort between LBNL, the Center for Sustainable Building Research, and the Alliance to Save Energy, help in this important decision-making methodology. These tools are not intended to replace whole-building performance simulations, but are targeted as tools to aid in the decision-making process early in the schematic design and development processes.

Keywords: fenestration, windows, window systems, high-performance window, glazing, window optimization, window selection, window design, decision-making tools, methodology, high-performance building, high-performance commercial building, energy, peak demand, carbon emissions

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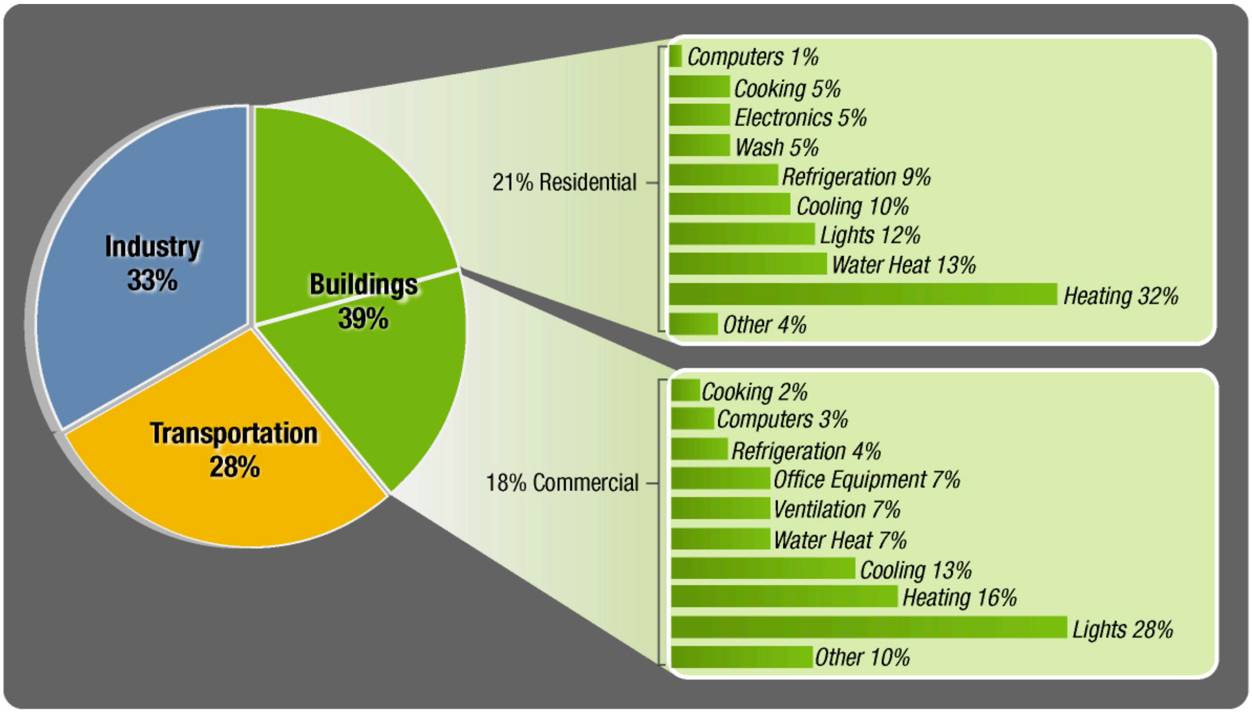
INTRODUCTION

According to U.S. Department of Energy's (DOE) office of Energy Efficiency and Renewable Energy (EERE), buildings are responsible for 39% of all energy consumption. As seen in Figure 1, 21% of the building energy consumption is residential and 18% is commercial. In residential buildings heating is the largest consumer of energy, and for commercial buildings lighting is the largest consumer. Heating, cooling, and lighting are all impacted by the fenestration systems.



Source: U.S. Department of Energy (DOE), 2008 Buildings Energy Data Book

Windows are an important contributor to the building envelope and can be an integral part of energy conservation strategies as well as to provide light, view and fresh air to the building's occupants. Recent research estimates that windows are responsible for 39% of commercial heating energy use and 28% of commercial cooling energy use—34% of all commercial space conditioning energy use. This is equivalent to 1.48 quads of space conditioning energy use—almost 1.5% of the total U.S. energy consumption (Apte and Arasteh, 2006). Approximately 2 quads of annual heating energy use in the United States are attributable to heat loss through windows, primarily in residential buildings (Arasteh, et al, 2006). These figures are significant.

Integrated design is important in achieving the energy-efficient goals of a building and the comfort and health of its occupants. To have a successful integrated design process, the design objectives must include: accessibility, aesthetics, cost-effectiveness, function/operations, historic preservation, productivity, security/safety, and sustainability. (Whole Building Design Guide, www.wbdg.org/wbdg_approach.php). When treating the building as an integrated system, fenestration options play an important role. Window system design and orientation will have an impact on many of these objectives, especially the energy use and environmental impacts. Therefore, the complex and inter-related building performance issues such as daylighting strategies, HVAC design and sizing, and shading options must be considered in the early design stages.

DECISION-MAKING METHODOLOGY

Decisions at several scales need to be made in a building design process. The larger scale issues of building placement on the site, building configuration, and overall layout usually occur first. In the early design stages, orientation, size, and shape of individual spaces and whether they have windows are established. Then the refinement of individual spaces and systems occurs, including defining window size and shape as well as the use of shading strategies and daylight control systems. Finally, glazing and frame type are specified with the desired properties.

As a building design decisions proceed from larger to smaller scale, discoveries are made that may raise questions about earlier assumptions. This is a normal part of the design process—ensuring that building design and performance goals are achieved. The challenge is that decisions made at different scales are interdependent. Because of this interdependent set of design parameters, decisions must be made within a given context.

The purpose of using simulation tools early in the design process is to provide designers with information they need to make knowledgeable choices about windows—particularly how to optimize for energy efficiency and to be aware of human factor issues such as glare and thermal comfort. Figure 2 illustrates a decision method in which a designer may begin to organize the interdependent parameters of selecting a window system design. There are two given conditions in any design—the climate and the building type (or space types within a building). Once these conditions are defined, issues about window orientation, daylight strategies, window size, shading strategies, and glass/frame type can be addressed.

A designer may be able to control all these variables during the design process. Or, in some cases these variables, for whatever reason, may be predetermined. In either case, the availability of simple and useful tools can aid in the decision-making process.

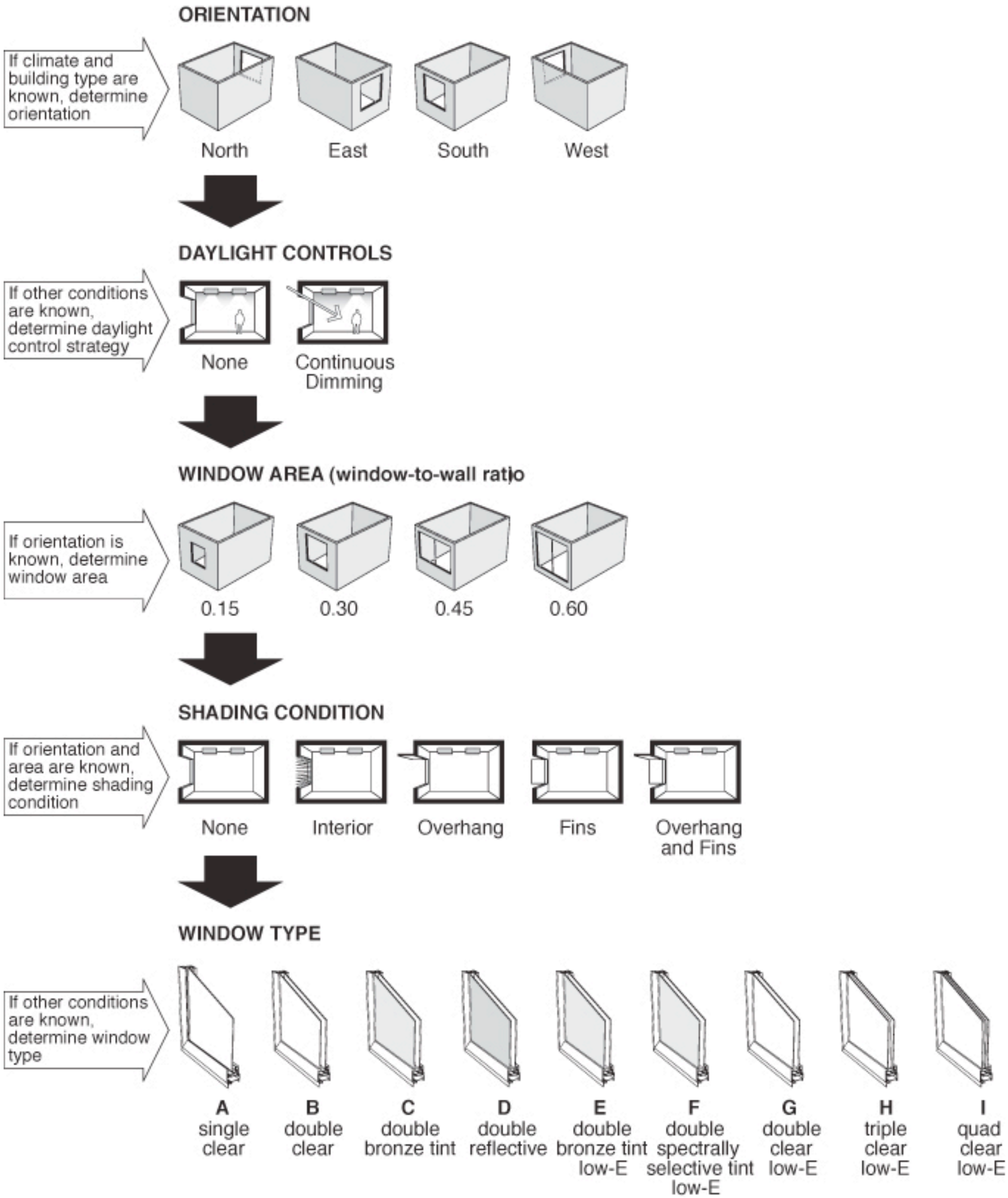


Figure 2. Decision-making process for window design and selection. Source: Window Systems for High-performance Buildings.

WEB TOOLS

Design decisions about windows are sometimes the result of relatively short-term thinking. Decision-makers either seek the lowest first cost or if a more efficient window is chosen, they seek a short-term payback based on current energy prices. Based on current events and global trends, it would be prudent to have a longer-term perspective when selection a window system that will be in place for 30 years or more. Simple web-based tools are available to aid in examining the long-term environmental impacts and cost implications of window design decisions.

Residential: Window Selection Tool

The basic thermal and optical properties of a window (U-factor, solar heat gain coefficient, and visible transmittance) can be identified if a residential window is properly labeled with a NFRC label. Residential consumers often still do not know how these basic properties influence annual heating and cooling energy use. The Efficient Windows Collaborative's (EWC) Window Selection Tool can help determine the most energy-efficient window selection for your specific needs. The annual energy use from computer simulations for a typical house in 100 U.S. cities can be compared for different window options (see Figures 3 and 4).

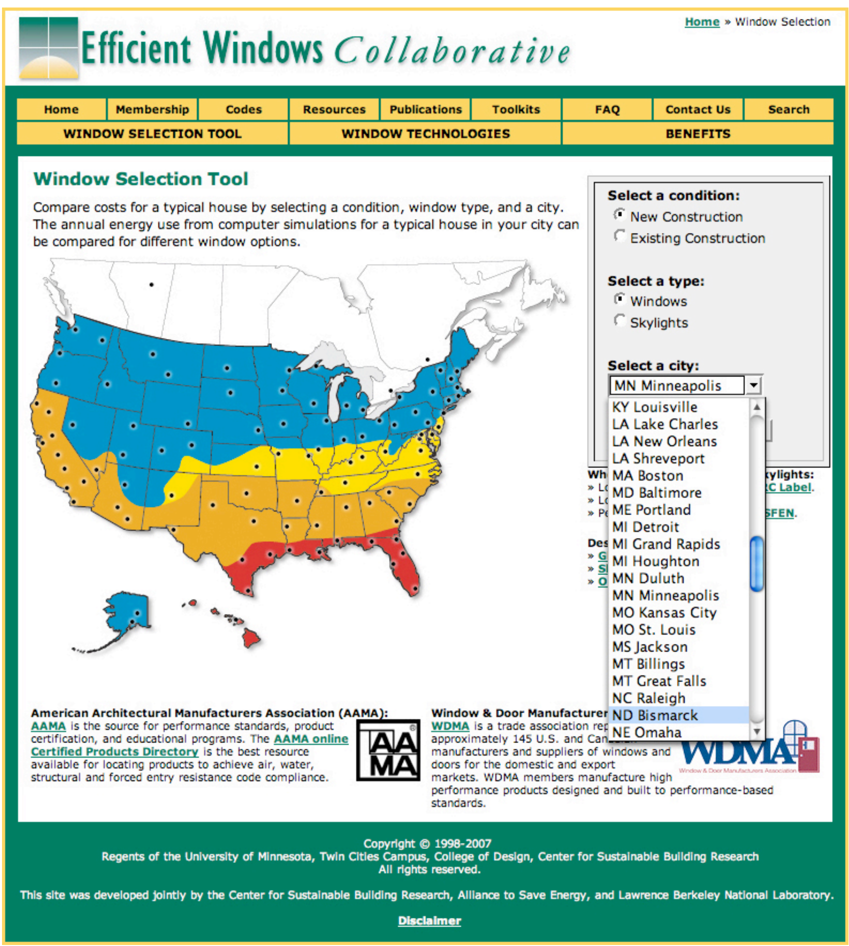


Figure 3. Window Selection Tool on the Efficient Windows Collaborative web site (www.efficientwindows.org).

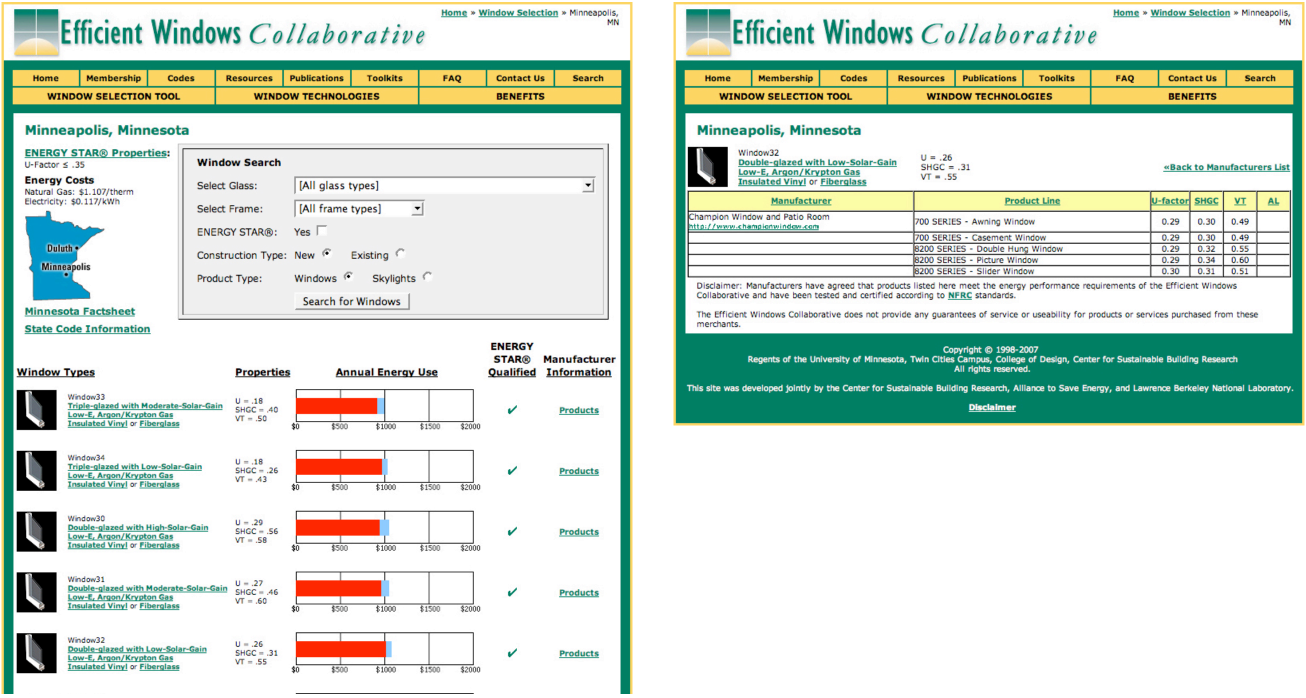


Figure 4. Results from the Window Selection Tool on the Efficient Windows Collaborative web site (www.efficientwindows.org).

Commercial: Façade Design Tool

Windows are one of the most significant elements in the design of a commercial building. Whether there are relatively small punched openings in the facade or a completely glazed curtain wall, windows are usually a dominant feature of the building's exterior appearance. Typically, aesthetics and costs are major factors in making design decisions about windows in commercial buildings. But, reducing unwanted heat loss and heat gain is a major energy-related issue in window design and selection and has major long-term cost implications. There is a need for an integrated approach to window design and selection that takes into account not only the environmental impact and cost issues but also the human factor issues of glare and thermal comfort.

The Façade Design Tool lets you choose the design conditions of a window and rank and compare the performance data in terms of annual energy, peak demand, carbon, daylight illuminance, glare, and thermal comfort for 7 U.S. cities. Using a large set of pre-existing parametrics of a 10-foot x 10-foot x 20-foot perimeter zone module, fenestration designs and scenarios can be ranked and compared with a graphical display of the data—allowing for the analysis of energy conservation strategies and human factor strategies early in the design process (see Figures 5 and 6).

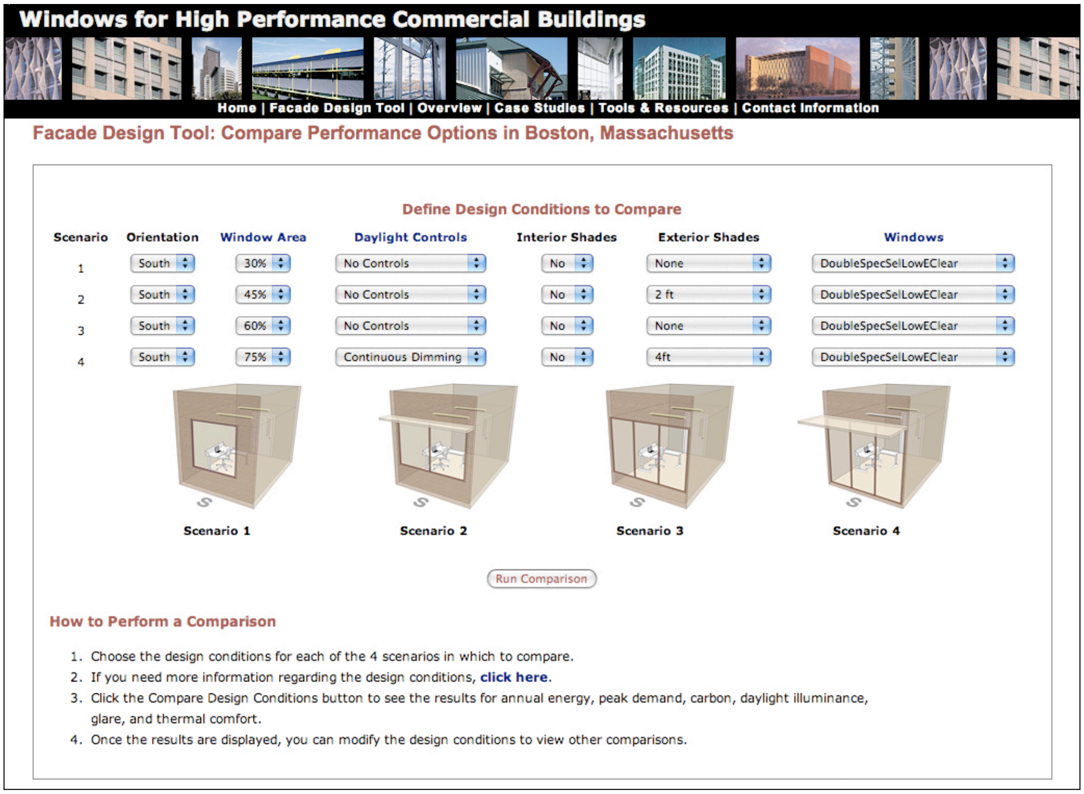


Figure 5. Comparison input screen of the Façade Design Tool on the Windows for High Performance Commercial Buildings web site (www.commercialwindows.org).

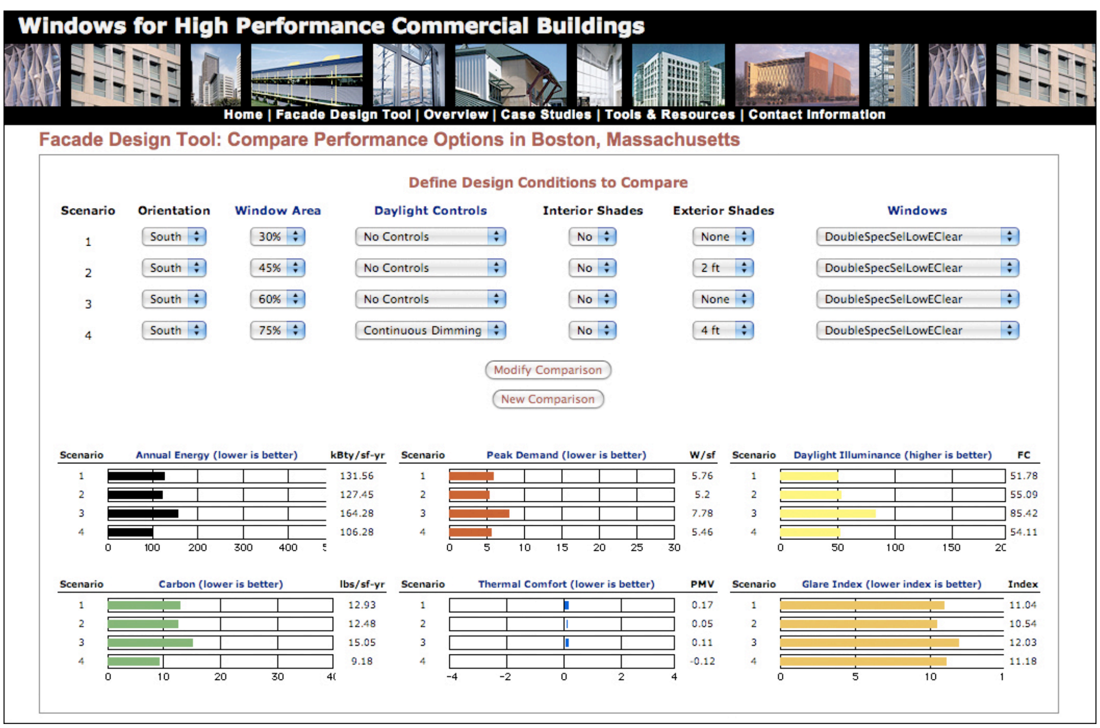


Figure 6. Comparison results screen of the Façade Design Tool on the Windows for High Performance Commercial Buildings web site (www.commercialwindows.org).

FENESTRATION SIMULATION TOOLS

There are varying fenestration simulation tools that are readily available. These tools, such as RESFEN (residential) and COMFEN (commercial), give the decision-maker early feedback on the impacts of design variables and aid in integrated design decisions. Both of these simulation tools are developed and maintained by the Windows and Daylighting Group at Lawrence Berkeley National Laboratory (LBNL).

In the suite of simulation software tools developed at LBNL, RESFEN and COMFEN use either the DOE-2 or EnergyPlus simulation engine, with parametrics defined in OPTICS, THERM and WINDOW (see Figure 7). All of these software programs are freely available from LBNL's web site: windows.lbl.gov/software.

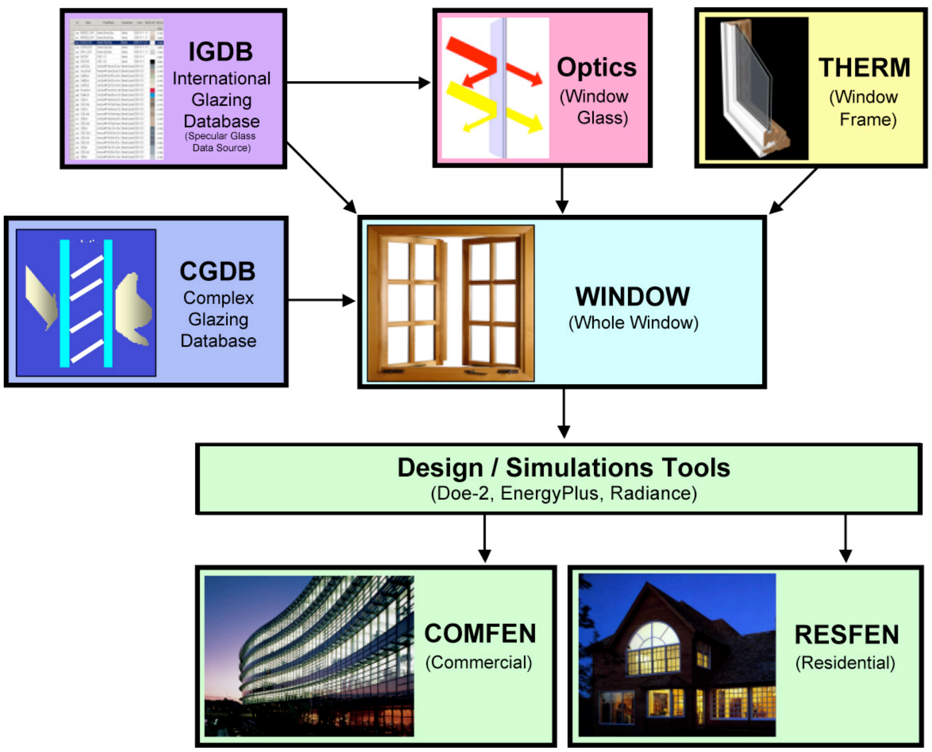


Figure 7. Software tools developed at Lawrence Berkeley National Laboratory (http://windows.lbl.gov/software).

RESFEN

Residential consumers are often confused about how to pick the most efficient windows type—windows that will help lower heating and cooling costs, increase occupant comfort, and minimize window condensation issues. The relative importance of efficient window properties (U-factor/R-value, solar heat gain coefficient, shading coefficient, visible transmittance) depends on site and building-specific conditions.

RESFEN, a computer simulation tool, helps residential consumers make informed decisions about window products. RESFEN calculates heating and cooling energy use and associated costs, peak heating demand, and peak cooling demand for defined window products. These defined window products can be the default generic set that is provided with the program, or the user can customize products by assigning specific thermal and physical properties. A scenario is defined by specifying house type, geographic location, orientation, electricity and gas cost, and building construction details (wall type, floor type, HVAC system). Users also specify size, shading, and thermal properties of the windows they wish to investigate. The thermal properties that RESFEN requires are: U-factor, solar heat gain coefficient, and air leakage rate.

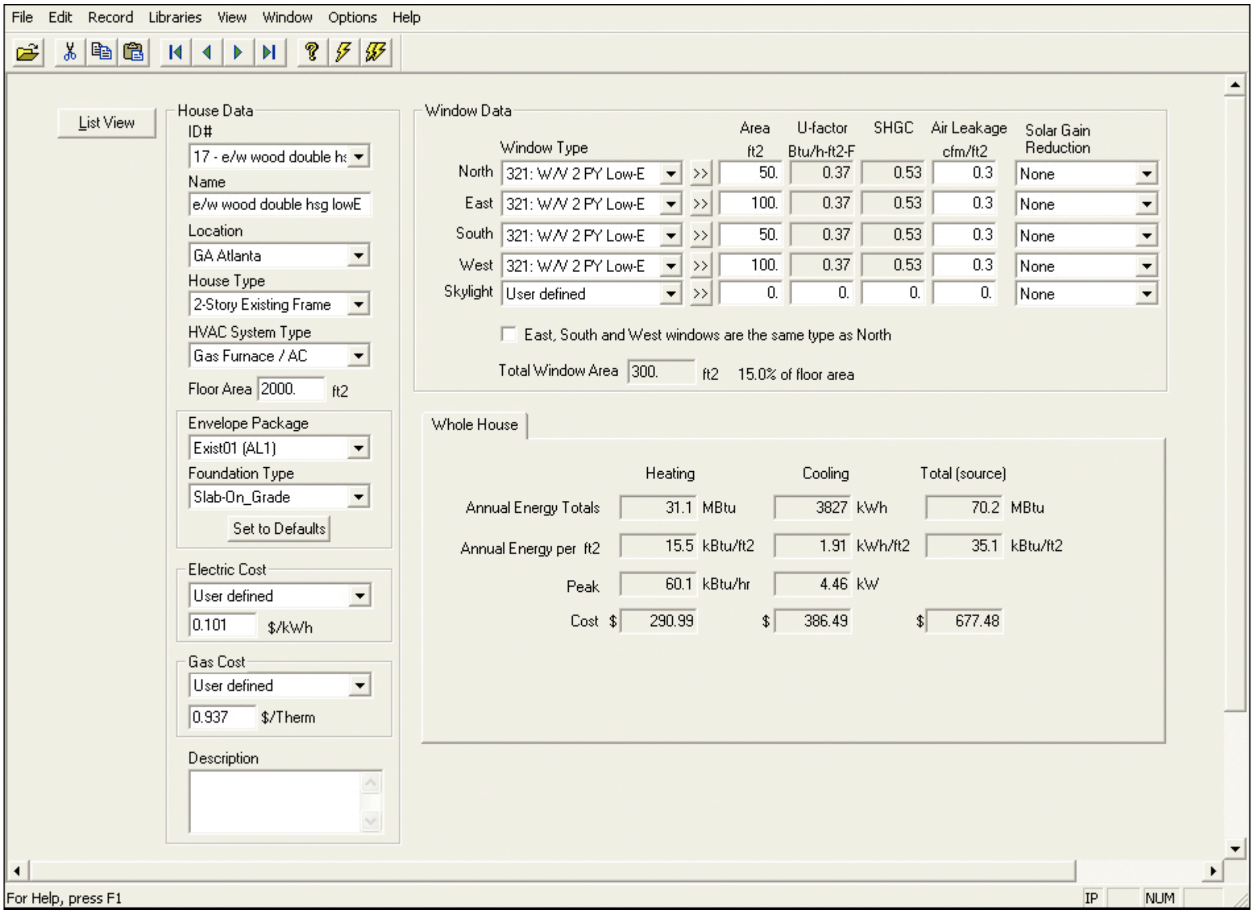


Figure 8. Main input screen of RESFEN.

COMFEN

COMFEN is a computer simulation tool to promote the design and selection of high performance fenestration systems by making simulated comparisons of alternative fenestration designs—from simple to complex glazing systems. It calculates heating and cooling energy use, peak heating and cooling demand, and visual and thermal comfort for specified fenestration system designs.

Early aesthetic design decisions often focus on the exterior façade of the building. Yet for an integrated design process, evaluation of design choices with respect to their energy and occupant comfort impacts are necessary. COMFEN aids in providing performance feedback early in the design process to answer certain strategic questions. What shading devices, if any, are appropriate and what are their impacts? What are the effects of daylighting controls when comparing tinted and non-tinted glass? What is the optimal glazing area?

These questions are not intuitively answerable without some sort of analysis of their interactive impacts on the rest of the building design and performance. Only a sophisticated, whole-building simulation will provide specific results for these types of questions. But, early in the design process, this type of analysis may not be resourceful or available.

COMFEN simulations are based on a perimeter zone model. The focus on the individual perimeter zones can then be generally applied to whole-building and site design. These simulations can inform a decision-maker on the effects of various parametrics such as orientation, window area, glazing type, shading strategies, and daylighting strategies—allowing for the development of energy conservation strategies early in the design process.

Figure 5. Scenario input screen of COMFEN comparing four design options.

Other Simulation Tools

Other whole-building and fenestration simulation and analysis tools are available. EFEN, produced by DesignBuilder Software, is an energy analysis software program for evaluating fenestration options in commercial buildings. EFEN is for the use in early stages of design to do comparative energy analysis of different fenestration options and to predict whole-building energy use and size of the HVAC system. EFEN, like COMFEN, uses EnergyPlus as it's simulation engine. EFEN has a licensing fee and provides education discounts. Whole-building modeling and analysis programs such as Google's Sketchup and AutoDesk's Ecotect have the ability (or have plugins available) to do energy and daylighting studies. These tools do not specifically focus on just on fenestration related impacts.

The MIT Design Advisor and Daylight 1-2-3 are web-based tools. The MIT Design Advisor is also for early use in the design process, targeted at conceptual design. Daylight 1-2-3 is a design analysis tool that supports daylighting-related design decisions in commercial buildings during the initial design and design development stages by predicting the daylighting and energy performance of sidelit and/or toplit spaces. This tool is to help designers develop climate-responsive daylighting design strategies, to optimize façade/ roof layout and orientation with respect to daylight and energy use, and to quantify energy savings from automated daylighting systems.

Tools such as RESFEN and COMFEN focus on comparative analysis of fenestration alternatives, while some of the tools described above offer additional user controlled input variables (HVAC system, complex building form, opaque envelope variations, etc.), and therefore may offer additional singular analysis results.

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